Psychological Monographs

General and Applied

324

1951

Vol. 65
No. 7

Adelbert Ames, Jr.

Visual Perception and the Rotating Trapezoidal Window

By

Adelbert Ames, Jr.

Edited by Herbert S. Conrad

Published by The American Psychological Association

Psychological Monographs:
General and Applied

MANUSCRIPTS should be sent to the Editor. For suggestions and directions regarding the preparation of manuscripts, consult the following article: CONRAD, H. S. Preparation of manuscripts for publication as monographs. *J. Psychol.*, 1948, 26, 447-459.

Because of lack of space, the *Psychological Monographs* can print only the original or advanced contribution of the author. *Background and bibliographic materials must, in general, be totally excluded*, or kept to an irreducible minimum. Statistical tables should be used to present only the most important of the statistical data or evidence.

CORRESPONDENCE CONCERNING BUSINESS MATTERS (such as subscriptions and sales, change of address, author's fees, etc.) should be addressed to the American Psychological Association, 1515 Massachusetts Ave., N.W., Washington 5, D.C.

VOLUME 65 WHOLE NO. 324
NUMBER 7 1951

Psychological Monographs:
General and Applied

Combining the *Applied Psychology Monographs* and the *Archives of Psychology* with the *Psychological Monographs*

HERBERT S. CONRAD, *Editor*

Visual Perception and the Rotating Trapezoidal Window

By
ADELBERT AMES, JR.
Institute for Associated Research
Hanover, New Hampshire

Accepted for publication, September 12, 1950

Price $1.00

Published by
THE AMERICAN PSYCHOLOGICAL ASSOCIATION
1515 MASSACHUSETTS AVE., N.W., WASHINGTON 5, D.C.

TABLE OF CONTENTS

PREFATORY NOTE

The Hanover Institute Division of the Institute for Associated Research has, for a number of years, been designing and constructing a series of demonstrations that, it was believed, would disclose phenomena which might be helpful in increasing the understanding of the origin and nature of visual perceptions. The first series of these demonstrations[1] disclosed phenomena related to the perception of the static aspects of the environment.

During the last few years the Institute has been engaged in developing a corresponding series of demonstrations disclosing phenomena related to the perception of motion. The Rotating Trapezoidal Window Demonstration, which is the subject of this paper, is one of this series that has just lately been designed and constructed.

The formulation of the inquiry that led to this investigation, the conceptualization of apparatus employed, the scientific methodology[2] followed, the explanations of the phenomena disclosed, and the formulation of the new questions raised by the disclosures, evolved from the writer's communion with the following individuals, each of whom has significantly contributed: Professors Hadley Cantril and Merle Lawrence, Dr. William H. Ittelson, and Dr. F. P. Kilpatrick, of Princeton; Professor Albert H. Hastorf, of Dartmouth College; Professors Hoyt Sherman and Ross Mooney, of Ohio State University; Professor Horace Fries, of the University of Wisconsin; and Professors Earl Kelley and Marie Rasey, of Wayne University.

The members of this group were drawn together by a common interest, and have been enabled to collaborate successfully for a number of years due to the effective administration of Mr. John Pearson, Director of the Institute for Associated Research.

Acknowledgement is due to Mr. Kimball Whipple for his aid in designing and constructing the apparatus and to Mrs. Alice Weymouth for her secretarial aid in writing the paper.

Special acknowledgement is due to John Dewey for his help and for the philosophical orientation he has contributed.

This study and related studies have been made possible by grants-in-aid from The Rockefeller Foundation and The Quaker Hill Foundation.

Adelbert Ames, Jr.

[1] These demonstrations and phenomena have been described in the following writings: (1) "The Nature and Origin of Perception: Preliminary Laboratory Manual for Use with Demonstrations Disclosing Phenomena Which Increase Our Understanding of the Nature of Perception," 1946–1947 (mimeographed); (2) Earl C. Kelley, *Education for What Is Real*, Harper, 1947, in which certain of the demonstrations are described; and (3) Merle Lawrence, *Studies in Human Behavior*, Princeton University Press, 1949, in which more of the demonstrations are described in more detail. The necessity of rewriting this preliminary material is recognized. However, such rewriting and publication are a major undertaking which circumstances prevent us from undertaking in the immediate future. Sets of these demonstrations can be seen at the Hanover Institute, Hanover, N.H.; at Princeton University; and at Ohio State University. Manuals of the demonstrations are in the course of preparation by Professors Hoyt Sherman and Ross Mooney of Ohio State University.

[2] See references 7 and 13.

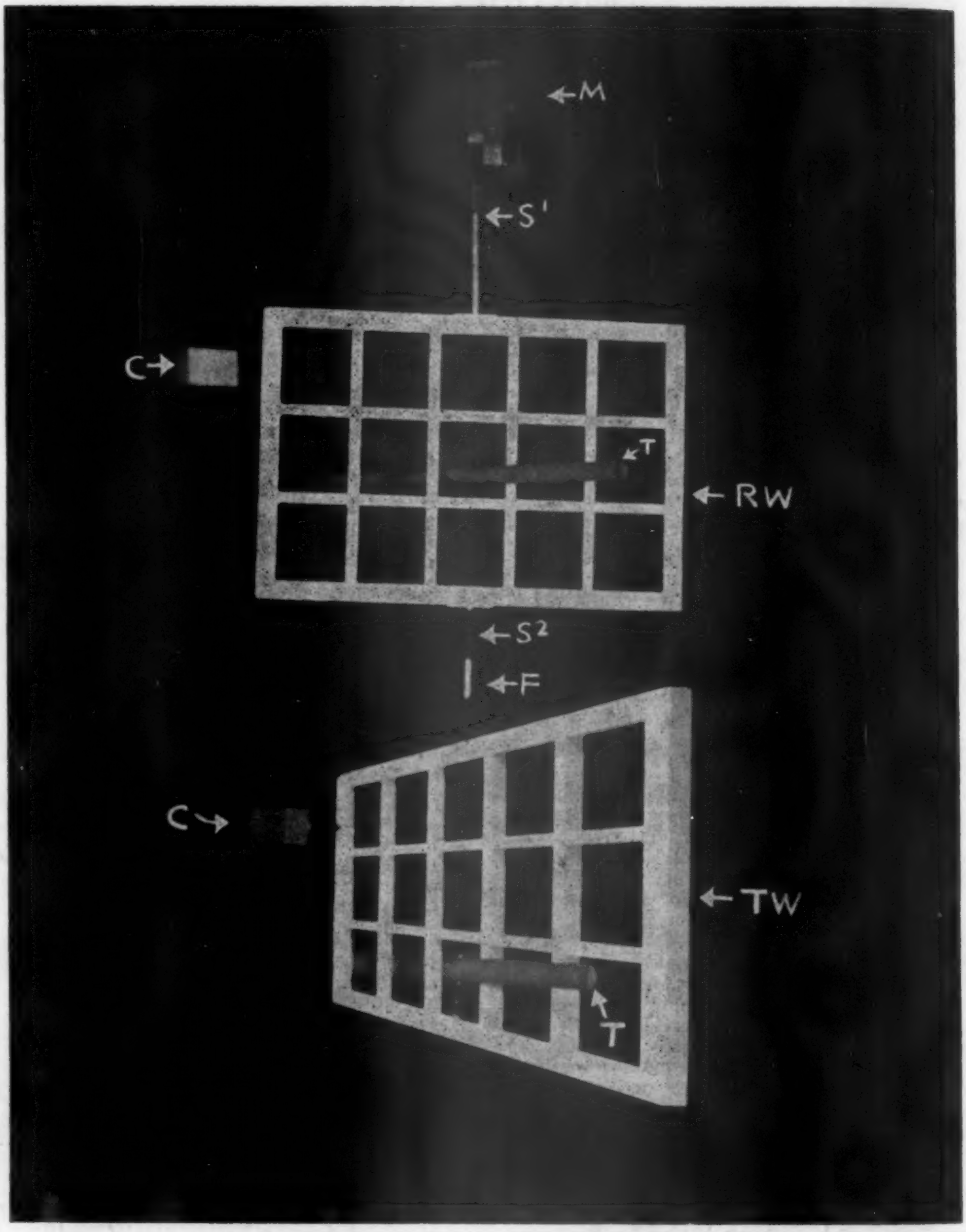


FIG. 1. Photograph of apparatus

The photograph was taken with the surfaces of the rectangular window and the trapezoidal window in the same plane, which was perpendicular to the optical axis of the camera. The dimensions of the rectangular window are: length, 23½"; height, 16½"; thickness, ¼"; width of outside frame, ½"; width of mullions, ¼". The outside dimensions of the trapezoidal window are: length, 19½"; height of long side, 23⅝"; height of short side, 12½"; thickness, ⅛".

CHAPTER I

DESCRIPTION OF APPARATUS

THE APPARATUS used in this demonstration was designed to enable observers experiencing the demonstration to perceive certain characteristic alterations of visual phenomena that result from varying the trapezoidal form of a rotating window.[1]

A photograph of the apparatus is shown in Figure 1. It consists of the rectangular window (see *RW*) suspended by a vertical shaft S', which is driven by an electric motor *M*, which is attached to the ceiling. The trapezoidal window *TW* is suspended on the vertical shaft S^2, which is rigidly fixed to the bottom of the window *RW*. On this shaft there is a sleeve *F* with two lock nuts so that the two windows can be set at any desired angle relative to each other. All the altered appearances can be seen irrespective of the relative angles between the two windows, but comparisons of alteration in size are more easily made when they are set in the general relative position to each other shown in Figure 2. When the motor is going, the rectangular window and the trapezoidal window rotate at the same speed about a common vertical axis. This arrangement enables the observer to compare the appearances of the two windows and note what alterations in his visual phenomena result from variation of the trapezoidal form of the rectangular window.

The speed of the motor *M* can be controlled by a rheostat. A convenient speed for most observations is around 3 to 6 rpm. It is also desirable to have a switch so that the motion of the windows can be stopped at any desired position of rotation. The direction of the rotation of the shaft *S* can be reversed by a device on the motor controlled by a string pull.

Small cubes *C* and *C* are attached to the upper edge of the shorter side of the trapezoidal window and in a corresponding position on the rectangular window, and paper tubes *T* and *T* are attached in the middle of both windows so that they extend out on both sides (see Fig. 1 and Chart I). The role these cubes and tubes play will become evident later.

The dimensions of the two windows are given in the caption of Figure 1. The trapezoidal window is cut out of thin aluminum. Its particular dimensions were arrived at as shown in Figure 2. *AB* represents the three-dimensional rectangular window tipped at an angle of 16½° to the line of sight of an observer at the distance of 10 feet with the right-hand side farther away; *CD* represents a plane tipped at an angle

[1] The significance of what is disclosed in an empirical investigation primarily depends upon the nature of the factor the experimenter selects to vary. It therefore seems important to explain why it was decided to vary the trapezoidal form of a rectangular configuration and, also, why the particular variation of the trapezoidal form was adopted. As this explanation is of necessity lengthy and would unduly interrupt the description of the demonstration, it seems advisable to add it as an appendix.

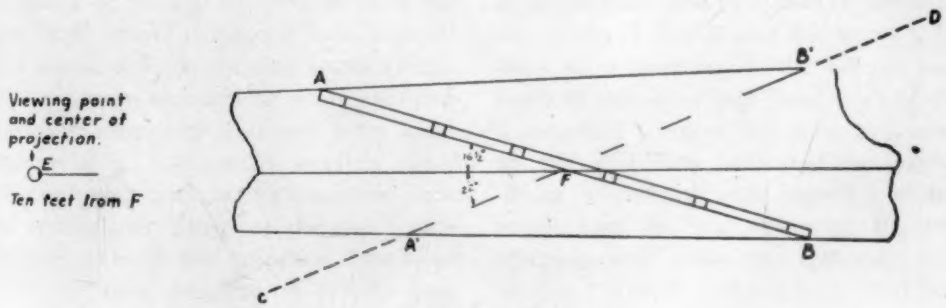


FIG. 2. Plan showing design of the Trapezoidal Window

AB represents the Rectangular Window set at an angle of 16½° to the line of sight *EF* ten feet from viewing point *E*. *A'B'* represents the Trapezoidal Window which is a projection from *E* of the Rectangular Window and its mullions on a plane *CD* tipped 22° to the line of sight *EF*.

of 22° to the line of sight, with the right-hand side nearer. *A'B'* represents the aluminum cutout of the projection of the window *AB* on the plane *CD*.

The projections of the shadows cast on the actual window by an overhead light are painted on both sides of this trapezoidal cutout. The trapezoidal window should be equally illuminated on both sides with low illumination in an otherwise dark room.

The alterations in visual phenomena that are related to the variation of the trapezoidal form of a window are empirically demonstrated by the differences between what observers with normal vision see when looking at the rotating rectangular window with its small cube and tube and when looking at the rotating trapezoidal window with its small cube and tube.

Chapter II

DESCRIPTION OF WHAT OBSERVERS EXPERIENCE WHEN LOOKING AT THE ROTATING TRAPEZOIDAL WINDOW AND APPENDED CUBE AND TUBE

The reader must realize that the phenomena disclosed by the demonstration can be comprehended only when they are personally experienced and that the following verbal and pictorial description of them can at best be only a second-hand communication. Moreover, the full significance of these phenomena can only be comprehended as they are related to other phenomena disclosed by the other demonstrations. However, described in general terms, all observers with normal vision, when looking at the rectangular window slowly rotating about a vertical axis, see a rectangular window of constant size and form at a constant distance rotating at a constant speed about a vertical axis, and the small cube and tube appear and move with it in an expected manner, and this holds irrespective of the distance, direction, or elevation from which they look, or whether they use one eye or two.

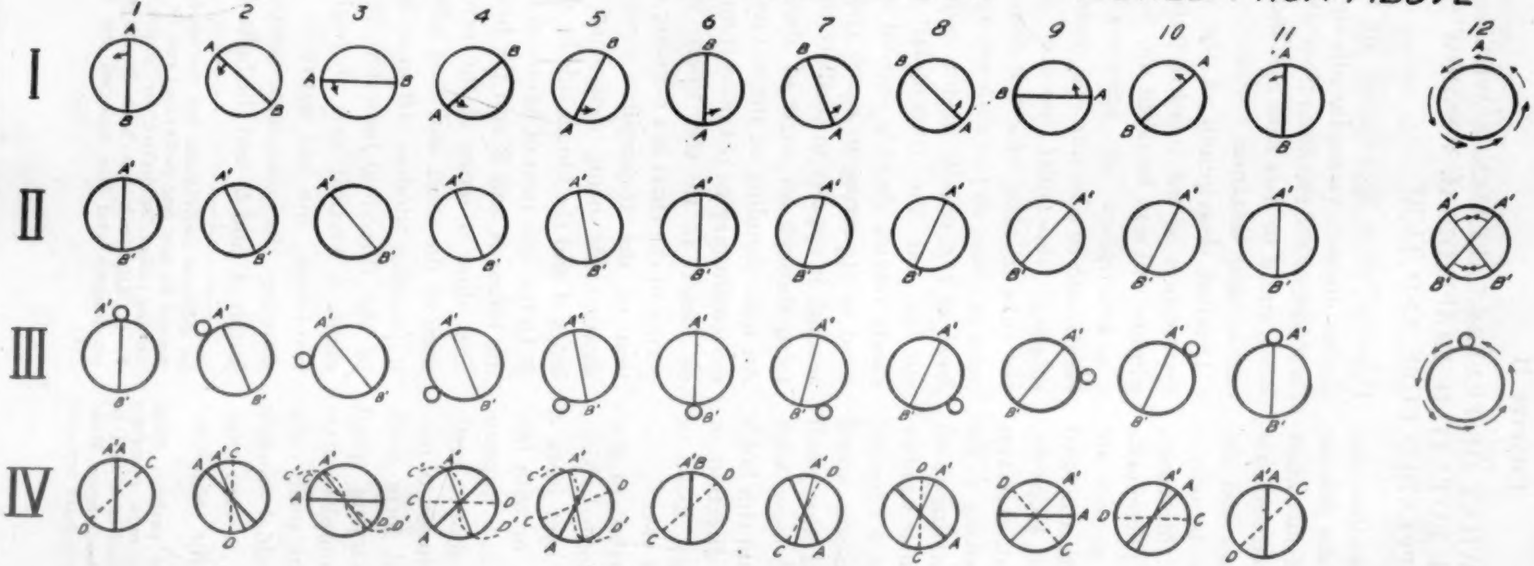
On the other hand, described in general terms, observers with normal vision, when looking (with both eyes from a distance of around 25 feet, or with one eye from nearer distances) at a trapezoidal window slowly rotating about a vertical axis, see a rectangular window of continually changing size and form oscillating at a continually varying speed through only a sector of a complete circle of revolution. They see the small cube sailing around the trapezoidal window and the tube bending at certain positions of revolution of the window.[1] However, these appearances are altered if the observer varies the distance, the direction, or the elevation from which he looks, and if he uses both eyes instead of one at near distance.

Detailed descriptions of the various appearances of the rotating trapezoidal window will now be taken up.

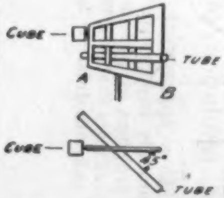
1. *Description of apparent movements both in direction and speed of the rotating trapezoidal window without the cube or tube, observed from a distance of about 10 feet with one eye at the level of the middle of the trapezoidal window.* As the trapezoidal window slowly rotates about a vertical axis, instead of appearing to rotate completely around, it appears to oscillate back and forth through an angle of about 100°. An understanding of the nature of this movement may be obtained from a study of Chart I. In the lower left-hand corner of the chart is a drawing in elevation of the trapezoidal window, the shorter side being designated by the letter *A* and the longer side by the letter *B*. In the four rows of figures in the chart the letters *A* and *B* and the heavy solid lines show a series of the actual positions of the short and long sides of the trapezoidal window *AB* as it is rotated in the direction indicated by arrows about a vertical axis through a full revolution, the last figure in the row showing the complete rotation. The letters *A′* and *B′* and the light solid lines

[1] The above appearances are perhaps those most commonly experienced by most observers and for purposes of communication it will be those appearances that will be dwelt upon. However, not only are different appearances reported by different individuals, but the appearances reported by any one individual can be altered by varying either "subjective" or "objective" factors. F. P. Kilpatrick has been investigating these phenomena and has reported his findings in (16).

CHART I – ROTATING TRAPEZOIDAL WINDOW — VIEWED FROM ABOVE



EXPLANATION OF FIGURES



TRAPEZOIDAL WINDOW SHOWING POSITION OF CUBE AND TUBE

ROW I — SHOWS BY THE HEAVY SOLID LINES A SERIES OF THE ACTUAL POSITIONS OF THE WINDOW (A-B) AS IT IS ROTATED IN THE DIRECTION INDICATED BY ARROWS ABOUT A VERTICAL AXIS THROUGH A FULL REVOLUTION, THE LAST FIGURE IN THE ROW SHOWING THE COMPLETE ROTATION.

ROW II — SHOWS BY THE LIGHT SOLID LINES THE PERCEIVED APPARENT LOCALIZATION OF THE WINDOW AT EACH OF THE POSITIONS SHOWN IN ROW I, THE LAST FIGURE IN THE ROW SHOWING THE APPARENT OSCILLATING MOVEMENT.

ROW III — SHOWS BY THE SMALL CIRCLES THE APPARENT POSITIONING AND MOTION OF THE CUBE WHICH CORRESPONDS TO THE ACTUAL MOVEMENT OF THE END OF THE WINDOW (A) TO WHICH IT IS ATTACHED (SEE LAST FIGURE IN THE ROW), THE LIGHT SOLID LINES SHOWING THE APPARENT POSITIONS OF THE WINDOW (A'-B').

ROW IV — SHOWS THE APPARENT POSITIONS AND DISTORTIONS OF THE TUBE AS THE WINDOW IS REVOLVED.
THE HEAVY SOLID LINES SHOW THE ACTUAL POSITIONS OF THE WINDOW.
THE STRAIGHT SHORT DASHED LINES SHOW THE ACTUAL POSITIONS OF THE TUBE.
THE LIGHT SOLID LINES SHOW ITS APPARENT POSITIONS.
THE CURVED SHORT DASHED LINES (SEE FIGURES 3, 4 AND 5) SHOW THE DISTORTIONS OF THE TUBE IN THAT PHASE OF THE ROTATION OF THE WINDOW.

show the apparent position of the short and long sides of the trapezoidal window. The top row of figures shows by the heavy solid lines marked *AB*, a series of the actual positions of the window (*AB*). The second row (*II*) shows by the light solid lines marked *A′B′* the apparent localization of the window at each of the positions shown in Row *I*, the last figure in the row showing the apparent oscillating movement.

By comparing the apparent positions shown in Row *II* with the actual positions shown in Row *I*, it can be seen that as the window rotates in a counterclockwise direction, it appears to move in the same direction as it is actually moving, but lags behind, appearing to move more slowly. When the window has rotated 90° (see third figure in Row *I*), it appears to have rotated only about 50° (see *A′B′*, third figure, Row *II*). As the window rotates farther than 90°, it appears very slowly to reverse its direction of rotation (see fourth figures in both Rows *I* and *II*). From then on it appears to rotate in a reverse direction to its actual rotation until the window reaches a position normal to the line of sight (see ninth figures in Rows *I* and *II*.) From then on it appears to move in the direction of the actual rotation until it reaches its starting position (compare first and eleventh figures in both Rows *I* and *II*).

The region of the apparent oscillating movement is shown in the last figure, Row *II*. The short side of the trapezoid appears to move from *A′* to *A′* and the long side from *B′* to *B′*. No part of the window ever appears to enter into the areas included between *A′B′* and *A′B′*. The angle of apparent oscillation with the particular trapezoidal form used is about 100°. The point of actual rotation where the apparent rotation starts to reverse is when the window is normal to the line of sight and thus subtends the largest visual angle.

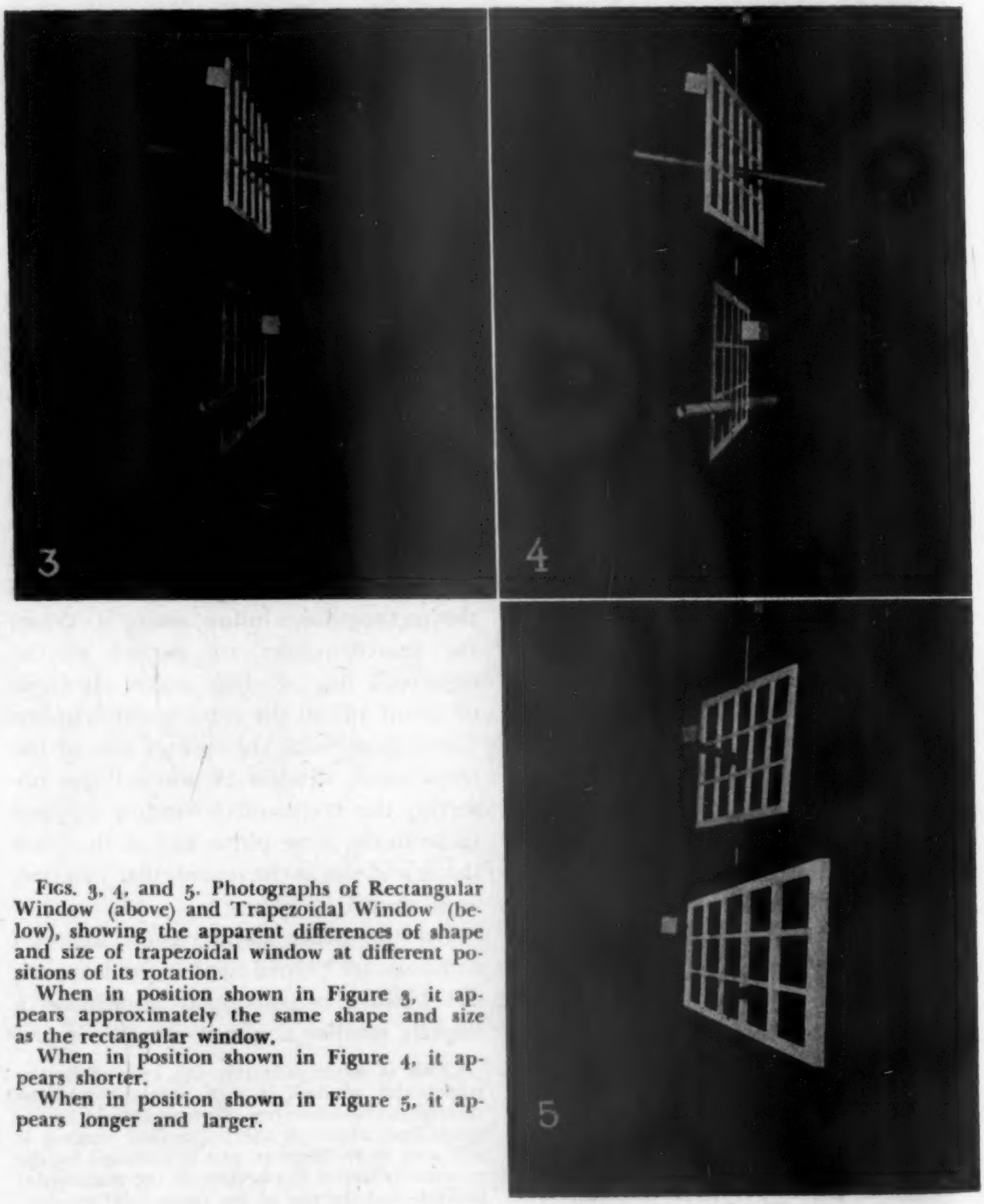
The apparent speed of movement varies greatly from the actual speed. As the window approaches a position normal to the line of sight, it appears to slow up gradually, come to a dead stop, remain stopped for an appreciable length of time, and then slowly to reverse its direction of movement.

2. *Description of apparent alterations of shape and size of trapezoidal window when observed with one eye from a distance of about 10 feet, eye at the same level as middle of window.* As the trapezoidal window slowly rotates about a vertical axis, it appears as a rectangular window,[2] but it appears to be continually changing in both shape and size. These alterations are made very apparent by comparing them to the shape and size of the rectangular window just above, which remain constant. This comparison can be best made when the trapezoidal window is positioned on its supporting rod so that it is at an angle of about 38° to the rectangular window above it. When the two windows are turned so the observer's line of sight makes an angle of about 16° to the rectangular window (see Fig. 2) with the shorter side of the trapezoidal window *A* toward the observer, the trapezoidal window appears to be in the same plane and of the same shape and size as the rectangular window, as is shown in Figure 3.

On the other hand, when the two windows are turned so that the trapezoidal window is positioned to subtend a slightly smaller angle, it appears in the

[2] This is more definitely the case when the trapezoidal window is seen alone. When the rectangular window just above it is seen at the same time, although the trapezoidal window is still seen as rectangular, one is bothered by the nonparallelism of the bottom of the rectangular window and the top of the trapezoidal window.

same place as the rectangular window, but it appears much shorter and gives the impression of being smaller, as is shown in Figure 4. And when the two windows are turned so that the trapezoidal window is approximately positioned as shown in the second figure of Row *I* of the chart, it again appears in much the same plane as the rectangular window, but in this case it appears much longer than the rectangular window and gives the impression of being larger, as is shown in Figure 5. In intermediate positions of rotation the trapezoidal window



FIGS. 3, 4, and 5. Photographs of Rectangular Window (above) and Trapezoidal Window (below), showing the apparent differences of shape and size of trapezoidal window at different positions of its rotation.

When in position shown in Figure 3, it appears approximately the same shape and size as the rectangular window.

When in position shown in Figure 4, it appears shorter.

When in position shown in Figure 5, it appears longer and larger.

appears of intermediate shapes and sizes.

3. *Description of apparent alteration of distance of trapezoidal window when observed with one eye from a distance of about 10 feet, eye at same level as middle of window.* As the two windows are observed while they slowly rotate, it is noticeable that when the trapezoidal window appears longer and larger, it also appears nearer. However, this appearance is equivocal and seems to be counteracted by conflicting indications such as those from the supporting rod and the rectangular window.

To test what would be observed free from other possible conflicting indications, the trapezoidal window was set up in a dark room so that its image reflected from a half-silvered mirror could be seen uniocularly directly in front of the observer in a field in which there was a series of posts that were binocularly seen, by which the observer could judge the apparent distance of the uniocularly seen trapezoidal window. The window was first set so that it appeared longer and larger and then set so that it appeared shorter and smaller. Only preliminary observations were made, but for two observers it appeared nearer when it appeared longer and larger, and farther away when it appeared shorter and smaller, than the rectangular window.

4. *Description of the apparent movement and changes in shape and size of the trapezoidal window when viewed from a distance of about 10 feet with one eye from levels above or below the middle of the trapezoidal window.* Whether viewed from above or below the level of the middle of the trapezoidal window, the window appears to oscillate and change speed and shape and size just as it appears to do when viewed with the eyes at the level of the middle of the window. However, instead of appearing rectangular as it revolves, it appears in trapezium form, the amount of distortion being related to the angular distance of the viewing point above or below. Its vertical axis also appears to oscillate back and forth. And, further, in certain positions of revolution it appears somewhat curved.

5. *Description of the apparent movements and alterations in shape and size of the trapezoidal window when observed with two eyes from a distance of about 10 feet and from greater distances.* If at a near distance of around 10 feet both eyes are used, what is perceived is a variable mixture of the above-described appearances and the appearances of an actual trapezoidal window rotating in the same way and at the same rates of speed as the rectangular window above it.[3]

When the observer, using both eyes, moves back from the windows to a distance of around 15 feet (the exact distance varying with the observer), the appearances of the trapezoidal window become less a mixture and more like what is observed monocularly. If the viewing distance is increased to around 20 or 25 feet (varying with the observer), the appearances of the trapezoidal window are almost the same as those experienced when it is viewed with one eye from a near distance.

Everything that has been said above holds true irrespective of the elevation of the observer's eye or eyes, and irrespective of his lateral position relative to the trapezoidal window. However, when his eyes are above or below, other second-order variations also are perceived.

6. *Description of apparent movement of small cube attached to the upper part of the short side of the rotating trapezoi-*

[3] One observer who had a markedly dominant eye and very poor stereoscopic vision got the same appearance with two eyes as he did with one from a near viewing point.

dal window when observed with one eye from a distance of about 10 feet, eye at same height as middle of window. As the trapezoidal window slowly rotates from its position as shown in Figure 1, Row *I*, of Chart I, the cube which is attached by a wire as shown in the drawing in the lower left-hand corner of the chart, appears to leave its point of attachment and float through the air around the front of the window, returning to its original attached position just before the trapezoidal window reaches its position shown in Figure 11, Row *I*, Chart I. The apparent position of the cube relative to the apparent position of the rotating trapezoidal window is shown by the figures in Row *III* of the chart. Throughout its course, in which it appears to rotate once about its own vertical axis, the cube appears of relatively constant size and appears to be going at a relatively constant rate of speed.

7. *Description of apparent movement and distortion of the tube which is suspended through the lower middle pane of the trapezoidal window, when observed with one eye from a distance of about 10 feet, eye at same height as the middle of the window.* The tube is suspended tipped at an angle of about 45° to the plane of the window, as shown in the drawing in the lower left-hand corner of Chart I. The appearances to be described can be seen with the tube at any inclination to the window, but are possibly more marked when it is at the inclination shown in the drawing.

As the trapezoidal window slowly rotates from its position as shown by the heavy solid line *A* in Figure 1, Row *IV*, of the chart, the tube shown by the dotted line *CD* appears to swing around with the trapezoidal window until the window starts to reverse its direction of rotation. When this occurs, the tube and the window appear to be rotating in opposite directions, the tube apparently moving clockwise and the window apparently moving counterclockwise. The tube then appears to swing until the left side of the tube comes up against the mullions on the left of the window and the right side of the tube comes up against the mullions on the right of the window. Up to that position the tube appears straight, but from there on it appears to begin to bend (see dotted lines marked *C′D′* in Fig. 3, Row *IV*, of chart) and seems to bend more and more (see dotted lines *C′D′* in Figs. 4 and 5, Row *IV*, of chart). When the trapezoidal window gets in the position shown in Figure 6, Row *IV* (chart), the tube suddenly snaps straight again and for the most observers remains straight during the remaining positions of revolutions shown in Figures 7, 8, and 9 of Row *IV* in Chart I.[4] The rate of movement of the tube also appears to change, as does its apparent length.

If the tube is set at right angles to the plane of the window instead of at an angle of 45°, it appears to bend and straighten out through the same sections of its rotation described above, although it starts to bend a little later and does not appear to bend quite so much. If the direction of rotation of the window is reversed, to many observers the tube appears bent in that section of its revolution where it appeared straight when it was revolving in its original direction and straight in that section where it appeared bent.

When both eyes are used at a near distance, variations in the appearances of

[4] There are a number of variations of these appearances (*cf.* 16).

the cube or tube are observable. These variations are related to variations in the appearances of the window. When both eyes are used at distances of around 12 or 15 feet, this also holds. When both eyes are used at distances of around 20 or 25 feet, about the same appearances are observable as were seen at near distance with one eye.

When the window is looked at with the eye or eyes at a level slightly above or below the middle of the trapezoidal window, appearances similar to those described above are observed, but they become markedly different as the distance of observation above and below is greatly increased.

The observer sees all the above-described appearances when he looks at the trapezoidal window with the appended tube and cube. If he looks at the rectangular window with its tube and cube, the appearances are quite different. The rectangular window appears constant in form, size, and movement; its cube appears at a constant relative position; its tube appears at a constant relative position, shape, and size; and none of these aspects changes when two eyes are used or when point of view changes in direction or in level. Of course, the subjective sense of the positioning of the window and its distance alters with its rotation and with the change of the point of view either in distance or direction or level.

8. *Description of apparent movements and alterations in shape and size of the trapezoidal window and of the cube and tube when viewed from different distances and different directions.* With variation of the distance of observation, the only marked alteration of all of the above-described appearances is in respect to the apparent changes in size of the trapezoidal window. At greater viewing distances the apparent alterations in size of the rotating trapezoidal window are greater.

With variation of the observer's tangential point of view there is no alteration of the above-described appearances. That is, irrespective of the direction from which he looks he will see the same oscillation, changes in shape and size of the trapezoidal window, movement of the small cube, and bending of the tube.

Although a given observer looking at the rotating trapezoidal window from different tangential points of view will perceive certain definite phenomenal happenings (i.e., the oscillating window, the flying cube, and the bending tube), it is important to note that the visual happening he sees from a particular viewpoint at a particular moment he *would not* see at that same moment if he were at another point of view. What he sees can be seen only at one particular moment from one particular point of view.

This also holds if the trapezoidal window is stationary and the observer is looking at it as he walks around it. As he walks around it, he will see all the phenomenal happenings he would see if he stood still and the window rotated. But the visual experiences he sees from one point of view can be seen only from that point of view. No other observer walking around with him can see what he sees at the same moment he sees it. So a number of observers standing around the rotating trapezoidal window at the same distance from its axis will all perceive the same visual happenings occurring, *but no two* of the observers will see the same visual happenings occurring at the same moment.

While it is clear that what each observer sees is determined by his viewpoint both in space and time, there are certain aspects of what each observer sees that are the same from any point of view at all times and for all other observers at other points of view and at other times. For example, the rectangular appearance of the trapezoidal window and the form and size of its small cube remain constant for all observers from all points of view at all times.

When the rectangular window is viewed from different distances and different directions, quite different phenomena occur. Irrespective of the distance or direction from which the rectangular window is viewed, the visual happenings an observer sees from a particular viewpoint at a particular moment he would see at the same moment if he were at another point of view. In other words, he would see a rectangular window of the same shape and size rotating at a constant rate of speed with the small cube in a constant relation to it and a tube of constant shape and length moving at a constant speed at the same moment, irrespective of his point of view. And a number of observers standing around the rotating rectangular window, irrespective of their distance, would perceive the same visual happenings occurring, *and all* observers would see the same visual happenings occurring at the same moment.

This concludes our attempt to communicate to the reader what he would have visually experienced if he himself had witnessed the demonstration. Next we will attempt to explain why one sees what he sees when looking at the rotating trapezoidal window, and why what he sees is so different from what he sees when he looks at the rotating rectangular window just above it. It is the same type of explanation that was formulated to account for the phenomena disclosed by the earlier, simpler demonstrations of the perception of the static aspects of the environment and of motion, and it seems adequately to account for the more complex phenomena described above. We have no illusion, however, that this account is the final word in the matter, but we present it because it seems to us the most intrinsically reasonable one that we can formulate at this time. Our hope is that its presentation will lead others to formulate still more intrinsically reasonable accounts.

Chapter III

EXPLANATIONS OF VISUAL PHENOMENA[1]

A. Explanation of the Variations in Appearance of the Trapezoidal Window

The appearances of the trapezoidal window give rise to many questions, among them the following:

1. Why does the trapezoidal window appear rectangular in shape?

2. Why does the rotating trapezoidal window appear to oscillate instead of rotate? Why does the trapezoidal window never appear to be where it actually is?

3. Why does the trapezoidal window, which is moving at a constant rate, appear to be moving at different rates?

4. Why does the trapezoidal window, which is constant in shape, appear of changing shapes?

5. Why does the trapezoidal window, which is constant in size, appear to be of changing size?

6. Why does the trapezoidal window appear rectangular when the eye or eyes are at the level of the middle of the window, but of trapezium form and sometimes curved when the eye or eyes are at other levels?

7. Why, when viewed with both eyes from a distance of around 24 feet (which is well within the distance at which stereoscopic vision is effective), does the trapezoidal window appear essentially the same as it appears with one eye?

It would seem apparent that there is no possibility of accounting for these appearances in causal terms of interactional effects between the objective phenomena and subjective appearances. The so-called "objective factor" that is varied is the trapezoidal shape of a rectangular window, i.e., making one side of a rectangular window longer and the other shorter. Among the many subjective appearances related to this variation is an alteration of the appearance of length and size. To say that it was caused by change in the trapezoidal form of the "object" in no way helps us to account for the apparent change in length and size. The obscurities that give rise to the above questions can be cleared up only by taking into account more particulars, i.e., other phenomenal processes that play a role in the situation, and understanding the nature of their relationships. This we shall attempt to do.

In what has been said so far, mention has been made of only two aspects of the situation, one, the characteristics of what the observer looks at, i.e., the so-called "objective" revolving trapezoidal window; the other, what the observer visually perceives. It is well known that there are many other phenomenal processes involved in every visual situation, among which is the physiological stimulus pattern that plays the role of relating the "objective" window and its subjective visual awareness.

As an aid in helping the reader understand the role played by the observer's physiological stimulus processes, we will introduce the use of a large artificial eye consisting of a lens corresponding to the dioptric system of the eye and a ground glass marked off in rectangular squares, corresponding to the retina. If this is set up pointing towards the trape-

[1] The explanations of the significances of the phenomena can at best be only partial explanations. For a more complete explanation, it is necessary to take account of other phenomena which are not disclosed by the demonstration now being considered, such as action, purpose, value, and emergent value-quality, which are beyond the scope of this paper. Some of these phenomena are disclosed by demonstrations described in the papers mentioned in footnote 1, Prefatory Note.

zoidal window, the observer can see on the ground glass, stimulus patterns of the same characteristics that exist on his retina when he looks at the trapezoidal window. If this artificial eye is set up at the same level as the middle of the trapezoidal window, he will note as the window revolves that: (*a*) the image on the ground glass goes through (*a*) series of varying trapezoidal forms; (*b*) the pattern on the ground glass is never rectangular; (*c*) there is no change in speed or oscillation of the trapezoidal pattern corresponding to the apparent change in speed or oscillation of the trapezoidal window; and (*d*) there is no change in form or size of the trapezoidal pattern corresponding to the apparent change in form and size of the trapezoidal window.

It is apparent that a knowledge of the characteristics of these stimulus patterns in themselves does not help us in understanding why the observer sees what he does when he looks at the rotating trapezoidal window.

Let us, then, try to see if a knowledge of the characteristics of a stimulus pattern will help us in understanding what we see when we look at the rectangular window. Let us point the artificial eye at the rectangular window and note the characteristics of the images formed on the ground-glass retina by the rectangular window. It will be noted that these images have the same general characteristics as the images of the trapezoidal window, although the appearances of the rectangular window are different from those of the trapezoidal window, as has been pointed out. It is evident that a knowledge of the characteristics of our stimulus pattern considered in connection with a knowledge of the object viewed and our perceptual awarenesses alone do not suffice to provide us with an answer to our questions.

Where shall we turn? Apparently a question we can ask gives us a lead, namely: "Why, when we look at the rectangular window, do we see a rectangular window, when the characteristics of its images formed on our retina are trapezoidal?" This question has extra significance because when we look at the trapezoidal window we see it, also, as rectangular, which means that the perceived rectangular form does not come from either the stimulus pattern or the object. If it does not come from the stimulus pattern or the object, whence does it come? This same question has occurred with all our previous demonstrations. In each case the most profitable and reasonable answer lay in bringing into consideration the past experience of the observer, and that consideration appears to be equally reasonable and profitable in this instance.

In his past experience the observer, in carrying out his purposes, has on innumerable occasions had to take into account and act with respect to rectangular forms, e.g., going through doors, locating windows, etc. On almost all such occasions, except in the rare case when his line of sight was normal to the door or window, the image of the rectangular configuration formed on his retina was trapezoidal. He learned to interpret the particularly characterized retinal images that exist when he looks at doors, windows, etc., as rectangular forms. Moreover, he learned to interpret the particular degree of trapezoidal distortion of his retinal images in terms of the positioning of the rectangular form to his particular viewing point. These interpretations do not occur at the conscious level; rather, they are unconscious and may be characterized as *assumptions* as to the probable significance of indications received from the environment. (Discus-

sions of the nature of assumptions and the evidence for their empirical origin may be found in references 1, 3, 16, 18, and 19.) A person's perception thus provides him with an awareness not only of the form of the "thing" he is looking at, i.e., "what it is," but also "where it is" relative to his viewing point (1, 2, 9, 13, 14, 18, 19).

Let us now take into account past experience in explaining what the observer sees when he is looking at the revolving rectangular window. Suppose the rectangular window is in an edge-on position when it starts to revolve. When it has turned a little, the image formed by its farther side will be shorter than that formed by its nearer side. The retinal image will be trapezoidal, the particular difference in length of its sides being determined by the length of the window and the observer's distance from it. As the window revolves, the lengths of the two sides will become more and more nearly the same until the window is normal to his line of sight, when they will be equal. Then the side which was the far side will become longer and reach its greatest relative length when at its nearest to the observer, i.e., when the window is in an edge-on position. As the window turns farther, the image of the now nearer side will decrease and the image of the farther side increase until the completion of the revolution. The observer interprets these changes in trapezoidal form as changes of position and interprets the continuing changes of position as a rotation of a rectangular window.

It would seem that the above begins to provide a basis for understanding why an observer sees what he does when he looks at the rotating trapezoidal window. Suppose the trapezoidal window starts rotating from the position shown in Figure 1, Row *I*, Chart I, when its shorter side *A* is farther away and the longer side *B* nearer. When it has turned a little (see Fig. 2, Row *II*, Chart I), the image formed by the farther side *A* will be shorter than that formed by its nearer side *B*. This difference in length is greater than the difference in length of the images of the far and near sides of the rectangular window above it. As it revolves, the image formed by the far side *A* will increase in length and that of the near side *B* decrease. But their relative change will not be as great as that of the images of a rectangular window at the same inclination. So the trapezoidal window will not appear to rotate so far or fast as the rectangular window above it, which is moving at a constant speed. When the trapezoidal window has rotated to a position normal to the line of sight, with the short side *A* to the left (see Fig. 3, Row *I*, Chart I), the image of its side *A* will still be shorter than the image of its side *B*, so it appears tipped back on the left in the position shown in Figure 3, Row *II*, Chart I. This is as far forward as the short side ever appears to come. With further rotation the vertical dimension of the image of the side *A* will increase in length and that of the side *B* decrease. But the image of the short side *A* of the trapezoidal window can never become longer than that of the long side *B*, and so it can never be seen as nearer.[2] However, this could not explain why the trapezoidal window appears to reverse its direction.

The explanation of the reversing phenomenon is apparently as follows: As the trapezoidal window starts to rotate from the position shown in Figure 3, Row *I*, Chart I, to those shown in Figures 5 and

[2] Compare demonstration with lines of changing length and balloons (1, Chap. II, Demonstrations 7, 8, 17, 18, 26, 27, and 28). See, also, references 15 and 19.

6, Row *I*, Chart I, the total horizontal angle that the trapezoidal window subtends to the eye decreases. At the beginning of this decrease the trapezoidal window appears tipped back on the left (see Fig. 3, Row *II*, Chart I). It has been learned from past experience with rectangular forms that a decrease of the total horizontal angle of our retinal images of a rectangularly perceived form which appears tipped away from us on the left could only take place if the side on the left went farther away. If it came nearer, the total horizontal angle of our retinal images would have to increase. So we interpret this decrease in the total horizontal dimension of our retinal stimulus pattern as a going-away of the left side of the window. That is, the window appears to reverse its direction of rotation, and as the left side of the window keeps coming towards us (see Figs. 3 and 4, Row *I*, Chart I), it appears to be going farther away (see Fig. 3 and 4, Row *II*, Chart I). A similar apparent reversal is seen to take place when the trapezoidal window has revolved to a position where the short side *A* is to the right (see Fig. 9, Row *I*, Chart I). It is due to these apparent reversals that the trapezoidal window appears to oscillate instead of rotate.

The above considerations seem to furnish a reasonable explanation as to why the rotating trapezoidal window (*a*) appears rectangular in shape, (*b*) appears to oscillate instead of rotate, and (*c*) appears to move at varying rates.[3]

[3] These alterations of motion related to unaccustomed variations of the trapezoidal characteristics of the stimulus pattern are very similar to phenomena revealed by another of our demonstrations which has to do with the origin and nature of the perception of "radial motion," the movement of objects toward or away from us. An account of this demonstration, which shows quite conclusively the role of assumptions in such perceptions, is included in reference 17.

But we have not yet answered the question of why the trapezoidal window appears to change in form and size. A reasonable answer to these questions seems to be based on our making use of variation in the trapezoidal characteristics of our stimulus pattern as indications to positioning of a rectangular configuration. When looking at the rotating rectangular window, the varying trapezoidal stimulus patterns have particular characteristics which give us indications of the position of the window in its rotation. For instance, when looking at the rectangular window tipped at an angle of 45° to our line of sight, the trapezoidal pattern formed on our retina will be the same shape whether the right side or the left side of the window is nearer us, and we will relate the two patterns and rectangular configurations of the same size and shape but at different inclinations.

But when we look at the trapezoidal windows, what happens is quite different. When the trapezoidal window is tipped 45° to our line of sight with the longer side *B* nearer us (see Fig. 2, Row *I*, Chart I), the shape of the trapezoidal image formed on our retina is quite different from that formed when the shorter side *A* is nearer us (see Fig. 8, Row *I*, chart). When the longer side *B* is nearer, there is a greater difference in the relative lengths of the sides of the trapezoid which could only be produced either by a rectangular window of the same height at a nearer distance or by a longer rectangular window at the same distance. When the shorter side *A* is nearer us, there is a lesser difference in the relative lengths of the sides of the trapezoid, which could only be produced by a rectangular window of the same length at a greater distance or by a shorter rectangular window at the same distance.

Since there are a number of indica-

tions that the distance of the window remains constant as it rotates, we translate the difference in the trapezoidal pattern on our retinas into differences in perceived length so that when it is rotating, it appears to be continually changing shape. When the indications of distance are eliminated, as was done in the preliminary experiment noted previously, we see the trapezoidal window as nearer when the longer side *B* is nearer, and farther away when the shorter side *A* is nearer (13). These considerations seem to furnish a reasonable explanation of why the rotating trapezoidal window appears to change shape (question 4) and size (question 5).

We now turn to question 6: Why does the trapezoidal window appear rectangular when the eye or eyes are at the level of the middle of the window, but of trapezium form and sometimes curved when the eye or eyes are at other levels?

The answer to this question is apparently the following: When our eyes are at the level of the middle of the trapezoidal window, the trapezoidal patterns on our retinas are identical with those that could be produced by some rectangular window at some inclination at some distance. When they are above or below, our stimulus patterns for the trapezoidal window are not trapezoids but trapeziums which, although similar to, are different from, the trapezium patterns that exist on our retinas when we look at a rectangular window from above or below.

A conclusive explanation of these appearances will be possible only when by a mathematical analysis (projective geometry) it has been determined just how the two types of trapezium patterns differ. But it seems probable that the trapezium patterns from the trapezoidal window are sufficiently similar to those from the rectangular window that we try to translate them into rectangular configurations even to the extent of seeing the window as curved. The apparent forward-and-back tipping of the trapezoidal window about a horizontal axis may be explained on the basis that the trapezium patterns are similar to those that would be produced by a rectangular window tipped about a horizontal axis.[4]

This brings us to the less significant question 7—why the trapezoidal window appears essentially the same when we use two eyes within distances at which stereoscopic vision is effective. The apparent answer is that in this situation we suppress the binocular cues and take account of the uniocular ones because uniocular cues result in perceptions which square better with what we have learned in past experience in dealing with windows. In other words, the uniocular cues have, on the basis of past experience greater prognostic reliability than do the binocular ones. This is confirmed by a number of our other demonstrations (see 1, Demonstrations 26 and 27, and 8, pp. 82 ff.). It might also be well to note here that parallax indications of distances, achieved by lateral movement of the head, do give rise to secondary alterations in the appearances of the trapezoidal window. They, however, do not aid one in seeing the trapezoidal window *as* a trapezoid rotating at a constant speed.

B. Explanation of the Appearance of the Small Cube[5]

The appearances of the cube give rise to at least the following questions:

[4] In the apparatus as constructed, the objective factor that is varied is the trapezoidal form. The phenomena just described make it apparent that different and interesting alterations of perception would be experienced if the window were actually made in a trapezium form. Presumably, if such a form were observed with the eye or eyes at the level of the middle of the window, its appearances would be similar to those experienced when the trapezoidal window is observed with the eye or eyes above or below the level of the window, and more exaggerated appearances would be experienced if such a window were observed from other levels.

[5] The reason for using the small cube and the tube in connection with the rotating trapezoidal window demonstration was to determine if and how the appearance and behavior of objects would appear to be altered when "put together"

1. Why does it appear to rotate in a circular path quite independently of the trapezoidal window to which it is attached?

2. Why does it appear to move at a relatively constant rate when the window to which it is attached oscillates at varying speeds?

3. How is it possible for it to appear separated from the trapezoidal window to which it is attached?

To the first question an answer which may come quickly to one's mind is that we see the window move as it does for the reasons given in Chapter II, and we see the small cube rotate in a circle at relatively constant speed because that is how it is actually moving. But this answer is not quite satisfactory because the previous chapter has made it evident that the appearances we see are not determined by what we are looking at but by our interpretation of our stimulus patterns.

Perhaps a better answer for why the small cube appears as it does and seems to move as it does can be derived from the following considerations. In the previous chapter, to understand the appearance and movement of the trapezoidal window it was necessary first to understand that we saw the rectangular window appear and move as it does because we assumed it was rectangular and made use of the varying trapezoidal characteristics of our retinal images as indications of its varying positions. Our perceptions of the movement of the small cube have a similar origin and nature. Due to the characteristics of our retinal image produced by light rays reflected from the small cube, we assume its size and other characteristics (3). In its rotation as the cube comes towards us, its retinal image increases, and we assume it is coming nearer to us; as it goes away from us, its retinal image becomes smaller, and we assume it is going away (see 1, Chap. II, Demonstration 17). The variations in the sizes of the retinal images and the rate of their movement across our retina, although not uniform or constant in time, are nevertheless so translated, and the cube appears to be moving in a circular path at a relatively constant speed.[6]

Let us now consider the question as to how it is possible for the small cube to appear to separate itself from the trapezoidal window to which it is attached. What has been said above explains why, if the cube were not attached to the window (i.e., if the cube were just above the window), we would see them following separate paths. That the cube does appear to separate itself from the trapezoidal window to which it is most evidently attached can only be explained on the basis that the indications causing the trapezoidal window to appear to move as it does and the cube to move as it does are accepted as definite and unequivocal, and cues indicating otherwise are suppressed.

Various three-dimensional objects were substituted for the cube and were attached in different ways. They all appeared to behave in the same manner. However, two-dimensional objects such as playing cards and small sheets of paper attached to the upper side of the shorter end of the trapezoidal window may or may not appear to move with the window, depending on how they are

in different ways with an objective configuration whose form was varied so that its appearance was altered.

[6] Why we see objects move in a circular path at a constant speed was given considerable study prior to the development of the Trapezoidal Window Demonstration. The Circular Motion Demonstration, which was devised as an aid to this study, is described in reference 17.

attached.[7] Apparently the factors involved in these phenomena are of the same nature as those disclosed in our demonstration of Togetherness and Apartness (1, Chap. VI).

C. Explanation of the Appearance of the Tube

The appearances of the tube give rise to at least the following questions:

1. Why does it appear to rotate quite independently of the trapezoidal window to which it is attached?

2. Why does it appear to move at varying speeds and at speeds different from that of the trapezoidal window?

3. Why does it appear to bend and change length?

The answer to the first question has already been covered by the explanations as to why the cube appears to rotate in a circular path quite independently of the trapezoidal window to which it is attached.

The answer to the second question appears to be that the tube seems to move at varying speeds (which the cube did not) because it is seen "together" with the window in a way that causes the observer to take account of its motion in relation to the apparent motion of the trapezoidal window.

The answer to the third question involves the necessity of taking into account the phenomenon of overlay. Overlay is one of the numerous indications which we take into account in formulating our presumptions as to the distances of objects. If an object is so positioned that it overlays or cuts off part of another object, we presume that it is nearer and that the other object is farther away. As has been demonstrated,[8] because of its high prognostic reliability, great weight is given this indication relative to the weight given other distance indications such as brightness, size, and parallax. With the rotating trapezoidal window and tube, this phenomenon of overlay comes into play.

As the window rotates we see the left half of the window overlaying the left part of the tube, and therefore in front of the tube, and the right part of the tube overlaying the right half of the window, and therefore in front of the window. As described, the tube and the window appear to be rotating about the same axis in opposite directions. When their paths cross, the observer has to make an interpretation of the happenings that are occurring to the characteristics of his retinal stimulus pattern. There are various possible interpretations he could make. He might keep the tube straight and whole and the window straight and whole, but then we would have to stop their motion; or he might ignore his overlay indications and see gaps in the mullions of the window to let the tube pass through; or he might see the window bend. If he keeps the window and tube in motion and the window flat and whole, i.e., without gaps in it, he has to see the tube bend.[9] It is this last interpretation that is most commonly made with this particular configuration, and this what most observers see. With this interpretation one also

[7] Alterations of appearances related to some variations in method of attachment of objects have been investigated by Kilpatrick (16).

[8] This phenomenon is demonstrated and considered in reference 1, Demonstrations 10 and 20.

[9] This phenomenon, i.e., the bending of the tube related to the apparent positionings of the trapezoidal window related to unaccustomed variations of the trapezoidal characteristics of the stimulus pattern, is very similar to another phenomenon made evident by another of our demonstrations, which has to do with the origin and nature of tangential motion, i.e., the movement of objects across our field of view. An account of this tangential Motion Demonstration is included in reference 17.

sees the tube increase in length when it bends because presumably only a longer tube could fill the length of space which the apparently bent tube fills.

All of this raises the question as to just why more weight is given to certain indications than to others, or why we insist on holding to certain presumptive aspects and giving up others. Apparently the answer is that we give weight to indications on the basis of their prognostic reliability.[10]

Some preliminary observations were made after replacing the tube with a rectangular box (a cigarette carton) with printing on it. With this setup the appearances changed. The box did not appear to bend as the tube does, or appeared to do so only very slightly; however, the window was still seen in the reverse of its actual position. This apparently means that the overlay indications were given no weight, or the window would be seen in its actual position. This line of investigation should be carried further.

There remains to explain why, when the tube is set at right angles to the plane of the window, it appears bent during a certain portion of its rotation when the window is rotating in one direction, but does not appear bent during the same portion of rotation when the window is rotating in the opposite direction. The only explanation that comes to mind is that we will accept the appearance of bending when it takes place gradually but will not accept seeing a straight tube suddenly bend. Observations have been made on this phenomenon, and they should be further checked. But if it is confirmed, it is an important disclosure and should be investigated.

TABLE 1

Constancy of Aspects of Visual Perception Experienced by One Observer When Looking from One Point of View at:

Rectangular Window, Cube, and Tube		Trapezoidal Window, Cube, and Tube from Level of Window		Trapezoidal Window, Cube, and Tube from above or below Level of Window	
Constant	Altering	Constant	Altering	Constant	Altering
"Windowness"*		"Windowness"		"Windowness"	
Rectangularity		Rectangularity			Rectangularity
	Inclination		Inclination		Inclination
Size			Size		Size
Shape			Shape		Shape
Motion			Motion		Motion
Direction†		Direction		Direction	
Distance			Distance		Distance

* The word "windowness" is used for the observer's awareness (resulting from his interpretation of certain characteristics of his stimulus pattern) of "something out there" (apart from other "things") of the nature of a window.

† "Direction" refers to the subjective sense of the direction of the window from the observer's egocentric center.

[10] Evidence for the prognostic nature of perception has been presented in reference 1, Demonstration 18, and has also been discussed in references 8, pp. 82 ff., and 16.

D. Summary

Before going on to consider further questions raised by the trapezoidal window, the material presented will be briefly summarized. The presentation up

to now has been an attempt (*a*) to describe to the reader the aspects of his visual experiences that would be altered when observing a rotating window whose trapezoidal form had been varied, and (*b*) to offer what appears to be a reasonable explanation of why these alterations in appearance are experienced. Table 1 may be helpful in making clear just what aspects of the observer's visual perception are not altered (remain constant) and what aspects are altered.

Briefly stated, the explanation as to why the altered aspects appear altered involves the taking into account of the characteristics of the stimulus patterns, which are essentially cryptogrammatic in nature, their translation in terms of the assumptions from past experience, the hypothesis that preceptions are not disclosures but essentially prognostic in nature, i.e., prognostic directives for action from the observer's point of view both in space and time, the weighing of "indications," sense of surety and lack of surety, value judgments. For more complete elaboration of these explanations, the reader is referred to references 2, 7, 15, 16, and 18.

But it should be realized that such explanations are only partial, for such questions as the following still remain to be answered: What kind of action? Action for what? If these questions are answered by saying: "Carrying out the purposes of the observer," the further questions arise: What kind of purposes? Purposes for what? The answers to these questions are beyond the scope of this paper. They have been considered in reference 6.

Chapter IV

CONSIDERATION OF FURTHER QUESTIONS RAISED BY THE DISCLOSURES

A. Common and Unique Aspects of Perception

An important additional question raised by the appearances of the trapezoidal window is, Why do perceptions of many aspects of the trapezoidal window differ at any one time between individuals with different points of view, or at different times for the same individual from the same point of view, while the perceptions of the same aspects of the rectangular window do not differ under these conditions? The answer apparently lies in the assumptions brought to each of these occasions by the observer.

When an observer who has had long past experience with rectangular configurations looks at the rectangular window, he assumes that what he sees is a rectangular configuration of a specific size and shape at a specific distance, due to the specific characteristics of his stimulus pattern, irrespective of the particular nature of its trapezoidal characteristics. At the same time he takes account of the trapezoidal characteristics of his stimulus pattern and translates them into a specific inclination of the rectangular configuration relative to his particular spatial point of view. As the rectangular window rotates and the trapezoidal characteristics of his stimulus patterns vary, he interprets each such variation as an alteration of its inclination. Hence he will see an assumed rectangular configuration of a specific size and shape at a specific distance rotating about its vertical axis. The observer has also learned from past experience just how the characteristics of these trapezoidal stimulus patterns will vary with every different point of view from which he observes the rectangular window. So, irrespective of his point of view when he looks at the rectangular window, he will see a rectangular configuration of a constant size and shape rotating at a constant speed.

The situation is quite different, as has been pointed out, when an observer having had long experience with rectangular configurations looks at the trapezoidal window. In the first place, because of his past experience he interprets the trapezoidal characteristics of the stimulus pattern as rectangular configurations.[1] In the second place, these varying trapezoidal characteristics are different from the varying trapezoidal characteristics that he has associated with any one particular rotating rectangular configuration. In the third place, as shown, *he keeps assuming different rectangular configurations as the trapezoidal window rotates.* As a result the significances into which he interprets the characteristics of his stimulus patterns are continually changing. They are different from moment to moment. They are also different from every different point of view.

It is believed that these phenomena are important for the light they throw on our understanding of those aspects of visual perception (*a*) that are similar or dissimilar from different points of view in space and time, (*b*) that are common, i.e., shared by two or more persons, and (*c*) that are unique to the individual. In Table 2, an attempt is made to present in easily comparable form

[1] Rectangular configurations are no more sacred than trapezoidal ones, and apart from his past experience there is no more reason for the observer's assuming the window is a rectangular configuration than a trapezoidal configuration.

TABLE 2

SIMILARITY OF ASPECTS OF VISUAL PERCEPTION EXPERIENCED BY ONE OBSERVER AT ANY ONE MOMENT IF HE COULD LOOK AT THE WINDOWS FROM DIFFERENT POINTS OF VIEW FROM THE SAME DISTANCE

Rectangular Window, Cube, and Tube		Trapezoidal Window, Cube, and Tube from Level of Window		Trapezoidal Window, Cube, and Tube from above or below Level of Window	
Similar	Dissimilar	Similar	Dissimilar	Similar	Dissimilar
"Windowness"		"Windowness"		"Windowness"	
Rectangularity		Rectangularity			Rectangularity
	Inclination		Inclination		Inclination
Size			Size		Size
Shape			Shape		Shape
Motion			Motion		Motion
	Direction		Direction		Direction
Distance			Distance		Distance

those aspects of an observer's visual perception that would be similar and dissimilar if he could look at the windows from two points of view at the same moment. With the rectangular window, all the aspects except inclination (tipping of the window) and possibly its direction relative to the observer, are the same from any point of view at any time or at a different time. With the trapezoidal window, none of the aspects except "windowness" and rectangularity (if the observer's eyes are at the right level) are the same from a different point of view or at a different time. That is, there are many appearances when looking at the rectangular window that are the same irrespective of the point of view in space and time which are not the same when looking at the trapezoidal window; or in other words, there is a "universality" of appearances of the rectangular window that is completely lacking in the appearances of the trapezoidal window.

It seems possible that the phenomenon referred to by the concept of "universality" is related to or part of the phenomenon referred to by the concept "common" between two or more observers (1, 3). This led to the making of Table 3,

TABLE 3

COMMON AND INDIVIDUALLY UNIQUE ASPECTS OF VISUAL PERCEPTION EXPERIENCED AT THE SAME MOMENT FROM THE SAME DISTANCE BY TWO OBSERVERS WITH COMMON ASSUMPTIONS BUT DIFFERENT POINTS OF VIEW

Rectangular Window, Cube, and Tube from Any Point of View		Trapezoidal Window, Cube, and Tube from Level of Window		Trapezoidal Window, Cube, and Tube from above or below Level of Window	
Common Aspects	Unique Aspects	Common Aspects	Unique Aspects	Common Aspects	Unique Aspects
"Windowness"		"Windowness"		"Windowness"	
Rectangularity		Rectangularity			
	Inclination		Inclination		Inclination
Size			Size		Size
Shape			Shape		Shape
Motion			Motion		Motion
	Direction		Direction		Direction
Distance			Distance		Distance

which is an attempt to present in easily comparable form those aspects of two observers' visual perceptions,[2] when looking at the windows, that would be either common, i.e., shared, or uniquely individual. With the rectangular window, both observers experience the same common aspects of "windowness"—rectangularity, size, shape, and motion. To both observers the direction, distance, and inclination of the window are personally unique. With the trapezoidal window, the only shared common aspects are "windowness" and rectangularity (if both observers' eyes are at the level of the window). Not only the aspects of direction, distance, and inclination relative to the individual points of view of the observers, but also the aspects of size, shape, and motion of the window are personally unique. Thus, there is a universally common world of appearances of the rectangular window that is completely lacking in the appearances of the trapezoidal window. Maybe the important questions are, Why is this? and What is the relation between this phenomenon and the phenomenon of similar and dissimlar appearances for one observer assuming different points of view?

TABLE 4

COMMON AND INDIVIDUALLY UNIQUE ASPECTS OF VISUAL PERCEPTION EXPERIENCED FROM THE SAME DISTANCE BY TWO OBSERVERS WITH COMMON ASSUMPTIONS BUT DIFFERENT POINTS OF VIEW WHEN LOOKING AT THE WINDOWS THROUGHOUT ONE OR MORE REVOLUTIONS

Rectangular Window, Cube, and Tube from Any Point of View		Trapezoidal Window, Cube, and Tube from Level of Window		Trapezoidal Window, Cube, and Tube from above or below Level of Window	
Common Aspects	Unique Aspects	Common Aspects	Unique Aspects	Common Aspects	Unique Aspects
"Windowness"		"Windowness"		"Windowness"	
Rectangularity		Rectangularity			
Inclinations—but at a different time		Inclinations		Inclinations	
Size		Size		Size	
Shape		Shape		Shape	
Motion		Motion—but at a different time		Motion—but at a different time	
	Direction		Direction		Direction
Distance		Distance		Distance	

If the rate of revolution of windows continually changed when looking at the windows throughout one or more revolutions, the only common visual aspects with the trapezoidal window would be "windowness" and rectangularity if eyes were at level of window.

If the assumptive worlds of the two observers differed in that one had been conditioned to rectangular configurations and the other to trapezoidal configurations, there would be no common visual aspects with any of the windows except "windowness."

If what was being looked at was emergent (not cyclical), further questions arise; but the emergent aspect could only be experienced in common to the extent that the two observers had common assumptive worlds and were experiencing the same types of stimulus excitations.

Moreover, the whole matter becomes more involved when we consider the common and unique aspects of appearances to two observers observing the windows as they rotate throughout one or more revolutions (see Table 4). A study

[2] No two observers have the same point of view because their eye or eyes cannot be in the same place at the same time. A lateral shift of one's eyes of only an inch or two causes a perceptible alteration of the appearance of the trapezoidal window.

of this table shows that, if what is observed is a periodically repeating phenomenon, the common and uniquely individual aspects of perception (except for direction) are the same for two observers looking at the rectangular window. They are also the same for two observers looking at the trapezoidal window except for the fact that the common aspects of perception occur at different times. The aspects that the observers see when looking at the different windows are different except for "windowness" and rectangularity. Thus, it would seem that certain aspects of the perception of periodically repeating phenomena and sequences are not related to specific points of view in either space or time. Further, it would seem that, in general, every perception is by nature an integration of universals in a "milieu" more inclusive than time and space and unique individual aspects related to the observer's point of view in space and time. The universal aspects can be abstracted and can be common to two or more persons, but the unique individual aspects cannot be abstracted or shared (common), nor can the perception as a whole.

This apparently brings up the question, Why are there more common aspects of appearances with periodically occurring phenomena than with nonperiodically occurring phenomena? It would appear that any satisfactory answers to these questions can be arrived at only when we have increased our understanding of the origin and nature of our assumptions, both conscious and unconscious, and the processes that are involved in the formulation of our perceptions.

B. Some Additional Considerations

Another question of importance is, Why are so many significant alterations in appearances related to a variation in the trapezoidal form of a rotating rectangular window, while no comparable alterations of appearances are related to other variations in the form of rectangular windows, such as length?

It required considerable space to describe and try to explain some of the many significant alterations of appearances related to variation in the trapezoidal form of the window. These alterations of appearances have no "correspondence" to the objective variation and are illusory in nature. Besides raising many significant questions, the phenomena disclosed apparently throw much light on our understanding of the origin and nature of perception and of our unconscious assumptions and the role they play in the formulation of perceptions. On the other hand, the alterations of appearances related to variation in the length-form of the window are relatively simple; these alterations of appearances "correspond" to the objective variation and are nonillusory. Consequently, the phenomena disclosed throw no light on our understanding of the origin and nature of perception or of assumptions and the role they play.

Why are such different consequences related to variations of such apparently similar objective factors? In trying to formulate a satisfactory answer, one seems to get into a confusion of mind resulting primarily from a failure to be clear as to the meaning of the words that have been used in the question. It may, therefore, be the proper place and time to try to analyze some of the terms employed. Such analysis of terminology would seem to be profitable only to the extent that we keep in mind a point made long ago by Helmholtz concerning perception; that is, that in the simplest percept there is involved a complex, in-

tegrative, judgment-like process based on experience:

As long as the premise of the conclusion is not an injunction imposed by outside authority for our conduct and belief, but a statement related to reality, which can therefore be only the result of experience, the conclusion, as a matter of fact, does not tell us anything new or something that we did not know already before we made the statements . . . (12, pp. 24–25).

Now we have exactly the same case in our sense-perceptions . . . in these cases no particular conscious conclusion may be present, yet the essential and original office of such a conclusion has been performed, and the result of it has been attained. . . .

These inductive conclusions leading to the formation of our sense-perceptions certainly do lack the purifying and scrutinizing work of conscious thinking. Nevertheless, in my opinion, by their peculiar nature they may be classed as *conclusions,* inductive conclusions unconsciously formed (12, pp. 26–27).

With this understanding of perception as a necessary basis we may utilize the "transactional" approach set forth by Dewey and Bentley (see 9, Chaps. IV, V, VI, and X), and the "operational" approach set forth by P. W. Bridgman (4) in pursuing our analysis to the extent of posing certain questions which open up what are believed to be highly significant lines of inquiry. For example:

1. What is referred to by the word "variation"? When we use the word variation (in regard to the rectangular window), we think of the "thing" that is changed as referring to something existing "objectively" as a whole apart in its own right (the rectangular configuration). We think of the "change" as referring to a modification of an aspect (i.e., the form) of the objective thing which also exists "objectively" apart in its own right. The demonstration shows that phenomenally the rectangular configuration that is varied does not exist objectively apart in its own right, nor does the aspect that is varied (i.e., its form) exist objectively apart in its own right, but that they exist (are) only because they are transactionally related to innumerable other phenomenal processes past, present, and future, among them the immediate "subjective" phenomena.

2. What is referred to by the word "alteration"? When we use the word alteration in regard to appearance, we think of the "thing" that is altered as something existing "subjectively" as a whole apart in its own right. We think of "alteration" as referring to a change in some aspect of "something" which also exists "subjectively" apart in its own right. The demonstration shows that phenomenally appearances that are altered are not "somethings" that exist subjectively apart in their own right, nor are the numerous aspects of appearances that are changed "somethings" that exist subjectively apart in their own right, but that they exist (are) only because of their being transactionally related to innumerable other phenomenal processes past, present, and future, among them the immediate "objective" phenomena.

3. What is referred to by the words "varying the trapezoidal form of a rectangular window"? We mean a changing of the form of a rectangular configuration and nothing else, and we think that as a result of such localized objective changes, subjective appearances may be altered. The demonstration shows that the "objective" and "subjective" factors do not exist as entities apart in their own right, but only as transactionally related, and that if one factor is varied, other factors alter only because we vary the total transactional relationship in which they are playing a role.

It seems clear, then, that each of the various aspects into which the total situation has been analyzed is not a fixed or static element but an "operation" as the word is used by Bridgman, and that the meaning of a term can only be clarified by giving an "operational" account of it. Further, no one term can have the same meaning in different operations. For example, from the "operational" point of view it is apparent that in the demonstration, when the words "trapezoidal form" are used to refer to an aspect of the "objective" operation, the phenomena they refer to are entirely different from the phenomena that are referred to when the words are used to refer to an aspect of the stimulus (physiological) operation or to an aspect of the perceptual (subjective) operation.

The above examples would seem to show that we cannot hope to formulate a satisfactory answer to many of our questions until we have become clearer concerning the referents of the words used in the question. Here we are faced by the difficulty that the phenomenal transactional relationships in even the simplest percept are so multiple and involved that no abstraction or word or expression can even implicitly refer to

them all. But this does not mean that abstractions and words are not indispensable. The efficacy of conceptual abstraction lies in its usefulness in inquiry when we have run up against a hitch in actual occasions of living. Such hitches are related to particular specific aspects of the total of the transrelated phenomena that constitute the transactional relationships. It is only by abstracting the specific aspects out of the total that we are able to understand and resolve the hitches.

It appears that, in using abstractions and words, we are always in danger of forgetting that they are only abstractions that refer to but never disclose the phenomena involved in transactional occasions, and we must continually endeavor as far as possible to be clear as to the "named" that is referred to by the "naming" we use.

EXPLANATION OF VARIATION OF TRAPEZOIDAL FORM OF RECTANGULAR CONFIGURATION[1]

It had become apparent from earlier investigations that what we are aware of when we look at a rotating object is not a disclosure of what is "objectively" taking place but a prognosis whose nature is related to assumptions arrived at from prior experience. To increase our understanding of the origin and nature of our perception of motion, it seemed necessary to understand more about the nature of the assumptions which play a role in our perception of motion. A possible procedure to disclose more about the nature of our assumptions was to vary, under controlled conditions, certain "objective characteristics" of a rotating object (in this case a rectangular configuration, a window) and determine if and how such variation would alter our perception and thereby possibly disclose more about the nature of the related assumptions.

The problem then arose as to what "objective characteristics" to vary. There are, of course, innumerable "objective characteristics" of a rotating rectangular window that could be varied, such as its chemical-physical make-up, weight, hardness, motion, form, shape, color, etc. It is apparent that light could be thrown on the nature of our visual processes only by varying visual aspects. It had become apparent from our earlier investigation that significant disclosures might result from variation of particular aspects of the objective form. The form of a rectangular configuration can be varied in a number of different days. It can be varied from a rectangular to a square form or vice versa by varying its length or height, or it can be varied in its over-all size by changing its length or height, or it can be varied in thickness. But with this type of variation of form, there would only be the expected alteration in perception "corresponding" to the "objective" variation. With such corresponding alteration of perception nothing is disclosed as to assumptions or the role they play in the situation.

A rectangular configuration can also be changed into a trapezoidal form. It had been found that with such type of variation there are related marked unexpected perceptual phenomena that might throw light on assumptions and the role they play. It was for this reason that it was decided to vary the trapezoidal form.

This brings us to the explanation of why the trapezoidal form was varied in the particular way in which it was varied. There are innumerable ways in which the trapezoidal form of a rectangular configuration can be varied (see Fig. 6, top). However, it seemed advisable to use a particular trapezoidal form which at a particular angle of inclination to the observer's line of sight produces light-ray impingements essentially the same as those produced by the rectangular configuration at some particular inclination to the observer's line of sight. There are innumerable trapezoidal forms that meet this specification (see Fig. 6, bottom). *A'B'*, representing a trapezoidal window, is a projection of *AB*, representing the rectangular configuration, and is an example of one of the innumerable possible forms. The particular form of *A'B'* depends upon the inclination of the rectangular configuration *AB* to the observer's line of sight *OG* and also upon the inclination of the plane *CD*.

The particular trapezoidal form that was used (see Figs. 1 and 2) was adopted for the following reasons: In earlier investigations it had been empirically found that when a trapezoidal figure of this form was rotated, it appeared through half its rotation to rotate in a direction opposite to its actual rotation.

A further preliminary investigation[2] was carried out to determine what degree of trapezoidal variation of what objective configurations would be most effective in producing (so to speak) alterations in the observer's perception. The following different objective configurations were tested: white 1/8" thick aluminum plane surfaces

[1] See Chap. I, footnote 1.

[2] Our experimental background prior to this preliminary investigation was as follows: In our demonstration to enable an observer to experience a "sense of surety" when the visual indications supplemented each other and a "sense of unsurety" when they were in conflict, we made use of a trapezoidal mullioned window with its short side nearer and its longer side farther away, which was seen in a reversed position (1, Chap. VIII, and 15, p. 97). We also made use of a similar surface which appeared in reversed positions in our demonstration to show that our perceptions of tangential motion were determined not by the actual motion of an object but by our interpretation of indications. But in both cases the surface would appear reversed only under especially controlled conditions when viewed monocularly from a particular stationary point of view. It was later found, thanks to a suggestion by Dr. Ittelson, that if shadows were painted on the surface to represent the mullions of a three-dimensional window, it would appear reversed under any ordinary conditions of illumination.

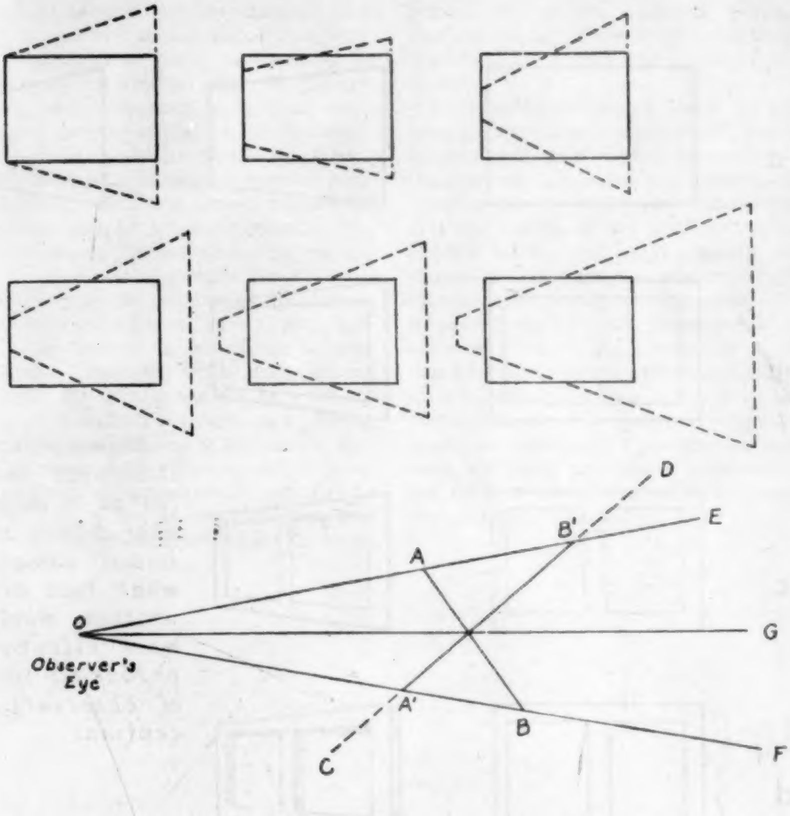


FIG. 6

The upper figures are examples of the innumerable ways in which the trapezoidal form of a rectangular configuration can be varied.

The lower figure shows that there are innumerable trapezoidal forms that will produce the same impingement patterns as a given rectangular form.

with various trapezoidal variations (see Fig. 7, row *a*); white frame-shaped plane surfaces (see Fig. 7, row *b*); white mullioned plane surfaces (see Fig. 7, row *c*); white mullioned plane surfaces on which shadows were painted to represent a three-dimensional window frame (see Fig. 7, row *d*); white mullioned plane surfaces with shadows with a different number of mullions or panes (see Fig. 7, row *e*); and, finally, white mullioned plane surfaces with shadows to represent a three-dimensional window frame with a different degree of trapezoidal variation (see Fig. 7, row *f*).

It was found that white plane surfaces (see Fig. 7, row *a*), although they "produced" alteration of the observer's perception, were least effective, irrespective of the degree of trapezoidal variation; that more effect was "produced" by the frame-shaped surfaces (see Fig. 7, row *b*); still more when mullions were added (see Fig. 7, row *c*); still more when shadows were painted on the surface to represent a three-dimensional window frame (see Fig. 7, row *d*); and still more when there were more mullions or panes (see Fig. 7, row *e*). It was also found that larger trapezoids produced more unequivocal effects than smaller ones.

It was further determined that with the last type of "window," if the trapezoidal variation (difference in the length of the parallel sides of the trapezoidal form—Fig. 7, row *f*) was apparent, the amount of the trapezoidal variation did not alter the general character of the visual phenomena experienced, although it did alter their degree. To insure that an adequate degree of alteration of the visual phenomena would be experienced, a considerable amount of trapezoidal variation was used (see Fig. 2).

As a final check a multiple-paned form (see

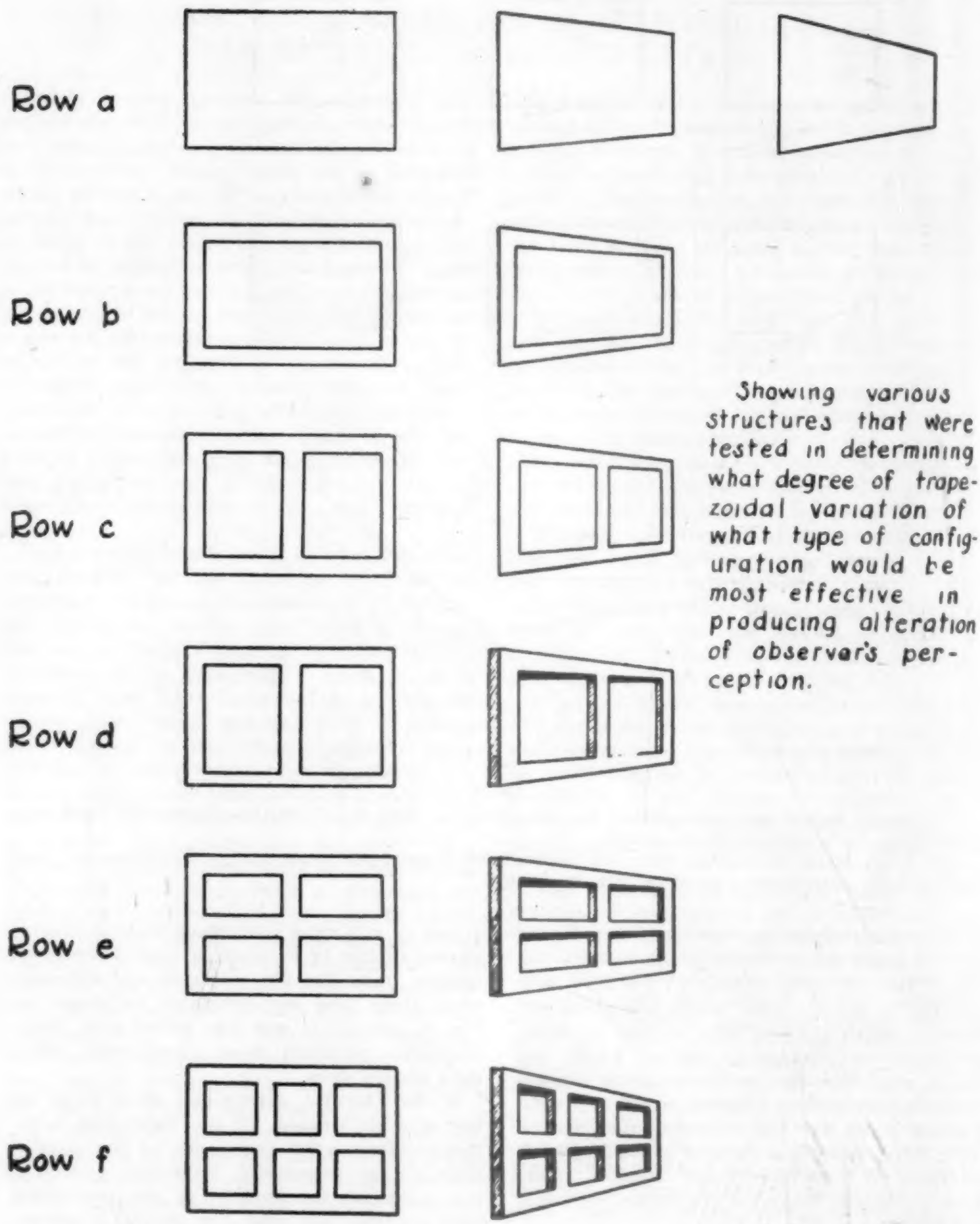

Row a
Row b
Row c
Row d
Row e
Row f
Showing various structures that were tested in determining what degree of trapezoidal variation of what type of configuration would be most effective in producing alteration of observer's perception.

FIG. 7

Fig. 7, Row *f*) without painted shadows (see row *c*) was tested, and it was found that with it the same phenomena could be observed as with the trapezoidal window with the painted shadows, the only difference being that some of the phenomena were slightly more equivocal.

One more point might be mentioned. Theoretically, if a three-dimensional rectangular comparison window is used, the varied trapezoidal window should also be three-dimensional, i.e., have actual thickness instead of having the appearance of thickness produced by painted shadows. This type of trapezoidal window is used in our demonstration of "surety" and "lack of surety" (see footnote 2) where the window was stationary. However, when seen in reversed position, the sides of the mullions are apparent when they shouldn't be seen on a window in that position, and give rise to indications that conflict with those from the trapezoidal form. These conflicting indications were obviated by painting the sides of the mullions black so that they could not be distinguished from the background. But as this would be difficult to accomplish if the window were rotating, it was decided to use a very thin window with painted shadows.

A theoretical objection could be raised that more than the trapezoidal form of the rectangular window had been varied because the painted shadows are not quite the same as the actual shadows on the rectangular window; moreover, that the width of the shadows varies as the window turns, and, also, because when the trapezoidal window is edge-on, it is much thinner than the rectangular window. However, it would appear that these minor variations have no effect on the alterations of perception that will be described, which apparently occur in spite of them. To have avoided all such theoretical objections it perhaps would have been better to have used a rectangular window cut from $\frac{1}{8}$" metal and also a trapezoidal window cut from metal of the same thickness without any painted shadows.

REFERENCES

1. Ames, A., Jr. *Nature and origin of perception: Preliminary laboratory manual for use with demonstrations disclosing phenomena which increase our understanding of the nature of perception.* Includes "Some demonstrations concerned with the origin and nature of our sensations (what we experience): A laboratory manual (preliminary draft)." Mimeo.*
2. Ames, A., Jr. *Nature and origin of perception: Literature dealing with the significance of the phenomena disclosed by the demonstrations.* Mimeo.*
3. Ames, A., Jr. *"Assumptions" and the role they play in perception.* Mimeo.*
4. Bridgman, P. W. Some implications of recent points of view in physics. *Rev. int. Phil.*, No. 10, 1949, 1–23.
5. Cantril, H. *Understanding man's social behavior.* Princeton, N.J.: Office of Public Opinion Research, 1947.
6. Cantril, H. *The why of man's experience.* New York: Macmillan, 1950.
7. Cantril, H., Ames, A., Jr., Hastorf, A. H., and Ittelson, W. H. Psychology and scientific research. *Science*, 1949, 110, 461-464, 491-497, 517-522.
8. Creighton, T. (Ed.) *Building for modern man.* Princeton, N.J.: University Press, 1949.
9. Dewey, J., and Bentley, A. F. *Knowing and the known.* Boston: Beacon Press, 1949.
10. Hastorf, A. H. The influence of suggestion on the relationship between stimulus size and perceived distance. *J. Psychol.*, 1950, 29, 195-217.
11. Hastorf, A. H. and Knutson, A. L. Motivation, perception and attitude change. *Psychol. Rev.*, 1949, 56, 88-94.
12. Helmholtz, H. von. *Physiological optics.* (Ed. by J. P. S. Southall). The Optical Society of America, 1925. Vol. III.
13. Ittelson, W. H. Size as a cue to distance. *Amer. J. Psychol.*, 1951, 64, 54-57, 188-202.
14. Ittelson, W. H., and Ames, A., Jr. Accommodation, convergence, and their relation to apparent distance. *J. Psychol.*, 1950, 30, 43-62.
15. Kelley, E. C. *Education for what is real.* New York: Harper, 1947.
16. Kilpatrick, F. P. Some aspects of the role of assumptions in perception. Unpublished Doctor's thesis, Princeton Univ., 1950.
17. Kilpatrick, F. P., and Ittelson, W. H. Some demonstrations concerning the perception of motion. *J. exp. Psychol.* In press.
18. Lawrence, M. *An inquiry into the nature of perception.* Princeton, N.J.: Institute for Associated Research, 1949.
19. Lawrence, M. *Studies in human behavior.* Princeton, N.J.: University Press, 1949.

* Preliminary informal statements for interdepartmental use.